



Regional Impact of Cyclone Sidr in Bangladesh: A Multi-Sector Analysis

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Abstract This research investigates the impact of cyclone Sidr on six regional economic systems of Bangladesh. The study uses secondary data on direct damages and corresponding changes in consumer spending and public/private investment expenditure. It employs input–output modeling and simulates the changes in national and regional output, income, and employment due to cyclone Sidr. Our findings indicate that coastal regions of Bangladesh—Barisal, Chittagong, and Khulna—are more vulnerable to cyclone disaster than are other parts of the country. The cyclone-induced loss of output is highest for Chittagong Division and income and employment losses are greatest in Barisal Division. The most affected sectors are housing services, agriculture, construction, and industrial activities. But sectoral losses vary widely across the regions. This research also finds that the present state of consumer spending and investment expenditure is not great enough to handle cyclone-induced output, income, and employment losses. It argues that investment decisions must consider regional patterns of output, income, and employment losses in different economic sectors to ensure cyclone-resilient development in Bangladesh.

Keywords Bangladesh · Cyclone Sidr · Input–output model · Regional impact · Sectoral impact

1 Introduction

Natural disasters occur frequently and often produce a large impact on Bangladesh's economic and social fabric. Apart from casualties, natural disasters cause direct damage that includes destruction of physical and social infrastructure, assets, and ecosystem production. Such damage also creates indirect interruption in economic activities; people change their consumption behavior, government mobilizes funds in order to tackle emergency situations, and difficult changes must be made in investment decisions. Some induced losses also take place due to interindustry linkages in an economic system. These impacts vary across disasters, different economic sectors (Loayza et al. 2009), and geographical regions (Noy and Vu 2010). Studies regarding the impact of natural disasters on the macroeconomy argue that the impact of natural disaster largely depends on the local economic characteristics of the country (Strobl 2012). The major determinants of natural disaster impact on economic systems are per capita income, size of economy, government expenditure pattern, institutional capacity, and ability for mobilization of resources (Noy 2009).

Yezer and Rubin (1987) find that disasters affect local economies negatively and such effects become insignificant when the whole economy is considered. According to Horwich (2000), because natural disasters are localized events, they may have limited effect on the whole economy. But very few studies have investigated the effects of disasters at a regional scale (for example, Cole 1998; Okuyama et al. 1999; Okuyama 2004; Tsuchiya et al. 2007; Tatano and Tsuchiya 2008). Disaster impact analysis at both spatial and sectoral levels remains limited in Bangladesh. The reason might stem from challenges inherent in the economic modeling of disaster impacts (Okuyama

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2007), data paucity, and difficulties in perception of sectoral linkages and their spatial dimension during disaster impact estimation (Haque and Jahan 2015). But understanding of how regional economic structures respond to the direct, indirect, and induced effects of disasters seems necessary for effective assessment of individual and local-level vulnerability. For example, disasters effect investment options in the form of social goods because disaster response requires expenditures on relief goods, reconstruction of houses, and reinstallation of utility services. Economic production also is inevitably curtailed. This occurs not only because damage to industrial plant must be repaired. Productivity gains are also deferred because capital intended for the development of new industries, as well as the construction of roads, bridges, and other growth-support infrastructure, must now be dedicated to the disaster recovery stage. Careful regional assessments are prerequisites for the preparation of effective disaster management plans (Rose 2004). Present research intends to understand the impact of cyclone disaster in Bangladesh both spatially and sectorally as a contribution to national disaster planning.

Bangladesh, with the Bay of Bengal on its southern border, has been ranked as the most vulnerable country to tropical cyclones (UNDP 2004). The country is exposed to tropical cyclones and associated storm surges not only because of its geomorphological placement but also due to its demographic and socioeconomic characteristics. On average, a severe cyclone with associated storm surge hits Bangladesh every 3 years (GoB 2009). Between 1877 and 1995, the Bangladesh coast was hit by approximately 1 % of the world's total tropical cyclones; but deaths from these cyclones comprised approximately 53 % of the world's total cyclone-induced deaths (Ali 1999).

Mahmoud (2008) finds that considerable regional disparity exists in Bangladesh in terms of Annual Development Program across different economic sectors before the 2007 cyclone Sidr. Therefore the regional economic effects of cyclone disaster are considered by the present research to represent a regional vulnerability that might help to channelize investment funding into a vulnerable region to mitigate cyclone-induced losses in Bangladesh. Here region is defined as the division—the largest administrative unit of Bangladesh (Fig. 1).

Our research traces available secondary data on direct cyclone damage as well as changes in consumer spending and investment expenditure due to cyclone impacts, selects cyclone Sidr as a disaster case study, develops damage scenarios for the cyclone, and estimates cyclone effects on national and regional output, income, and employment. In the absence of primary data at a regional level, secondary data are used to fill the gaps related to induced effects of the cyclone Sidr disaster. An important feature of this

research is its attempt to analyze short- and long-term disaggregated economic effects spatially. The research also investigates the ripple effects of post-disaster investment expenditures throughout Bangladesh's national and regional economies.

2 Regional Disparity in Bangladesh: An Overview

The history of regional differences of economy in Bangladesh dates back to the preliberation period. During the second and third 5-year Plans of what was Pakistan in the 1980s, economic activity and infrastructure development were focused mainly in the three major urban areas of Dhaka, Chittagong, and Khulna. This narrow spatial focus for development created inequalities among the regions of Bangladesh (Islam 1978). After the emergence of Bangladesh from the former East Pakistan, several successive 5-year Plans were produced to promote the development of a newly liberated country. Dhaka, the capital city of the new state, always received the major share of all investments. As the country's second largest city, Chittagong also started to receive an important share of development expenditures.

Since the 1980s the development approach had a new dimension: the establishment of "growth centers," which started with a noticeable resemblance to Francois Perroux's (1950) "growth poles," and supported rapid growth of farm and nonfarm sector production and marketing activities. The development of rural infrastructure—including roads, bridges and culverts, market places, and drainage and irrigation channels—was promoted as the major element of the new development strategy. The employment impact of this type of development was huge. But regional inequalities started almost immediately to take a wider shape. Using the GINI index for income distribution inequality, Bahauddin (1989) proved that interregional disparities exist in Bangladesh in terms of specific physical facilities (water supply and sanitary facilities, electricity connection, and so on), which have a close association with socioeconomic variables.

Meanwhile the industrial sector started to develop in the agriculture-based economy of Bangladesh. Agro-based industries, garment industries, and other large and small manufacturing industries flourished. The share of agriculture sector in national GDP, which was 41.77 % in 1984–1985, decreased to 22.83 % by 2003–2004 before the impact of cyclone Sidr. At the same time, the industrial sector share of GDP had risen almost three times, reaching 27.80 % from 9.86 % (PC 1998; BBS 2004). But the problem was that this industrial growth was concentrated in a few urban areas, which initiated and encouraged Hirschman's (1958) "polarization effect" and consequent imbalanced regional development.

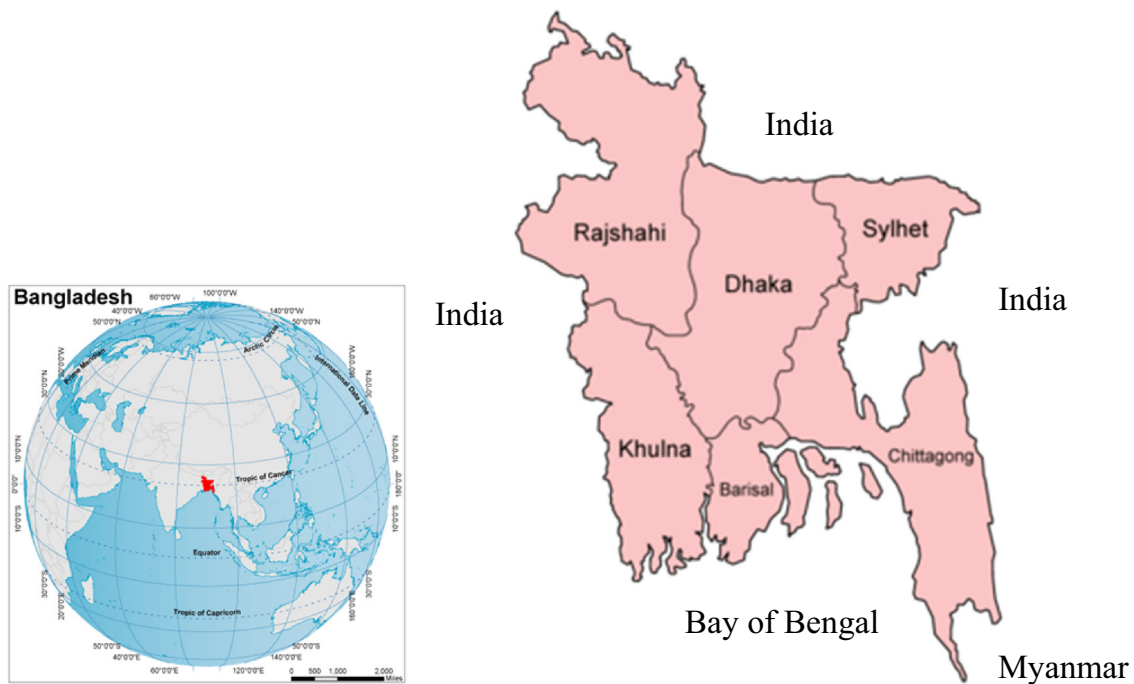


Fig. 1 Bangladesh in the regional and global context (left); Bangladesh with its six divisions/regions (right)

Source <http://mapall1009.dd-dns.de/bangladesh-earth-map>

The effects of such interregional imbalances are reflected in an excessive concentration of population and economic activities in the Dhaka region. This spatial myopia limits the economic potential of other regions and restricts the expansion possibilities of the economy, the improvement of living standards, and the increase of social welfare facilities. Table 1 shows population distribution and GDP for six regions of Bangladesh. In 2011, nearly 53 % of the country's total population lived in Dhaka and Chittagong regions with densities of 1539 and 964 people per km², respectively. Chittagong had the highest (around 48 %) share of urban population with respect to regional total population. During

2006–2007, just before cyclone Sidr, the estimated GDP of Dhaka was USD 16,516 million, which was almost 2.5 times that of Chittagong (country's second largest city) and 11 times that of Sylhet (the estimated GDP was the lowest in 2006–2007) regions respectively.

Given the population distribution and GDP contribution of the regions of Bangladesh, a comprehensive understanding about the impact of common disasters on regional economies is necessary to ensure regional productivity. The findings may also facilitate integrated and comprehensive formulation of regional policy and their efficient implementation.

Table 1 Regional distribution of population and gross domestic product (GDP)

Regions/divisions	Total population, 2011	Density (people/km ²)	Share of total population in the national total population	Urban population, 2011	Share of Urban population in the regional total population	Estimated GDP (Million USD), 2006–2007
Barisal	8,325,666	637	5.80	2,863,635	34.40	1872
Chittagong	28,034,684	964	19.52	13,485,266	48.10	6728
Dhaka	47,424,418	1539	33.01	15,465,391	32.61	16,516
Khulna	15,687,759	712	10.92	2,822,121	17.99	4240
Rajshahi	34,272,616	1010	23.86	5,426,093	15.83	7632
Sylhet	9,910,219	794	6.90	1,462,711	14.76	1538
Bangladesh	143,655,362	1015	100.00	41,525,217	28.91	38,525

Source Population data were extracted from BBS (2013). In the absence of regional GDP data for the stated year, they were estimated from the earlier (1995–2000) GDP data for regions using regression analysis. The regional GDP for the year 1995–2000 were collected from BBS (2002)

3 Model Selection for Impact Estimation

Since the mid-1990s, assessment of the economic impacts of natural hazards and disasters has received increased attention from researchers. The availability of improved data on disaster damages has helped researchers to estimate losses using various economic modeling frameworks. Input–output (IO) models, computable general equilibrium (CGE) analysis, and social accounting matrix (SAM) were widely used frameworks for the stated purpose. Each of these techniques has advantages and disadvantages. The IO model requires relatively less data and can comprehensively trace interaction among different sectors of an economy. But the model is criticized because of its linear and static nature. Other drawbacks of the IO model include its incapacity to respond to price change (Rose 2004) and economies of scale in production (Wilson 1974; Miller and Blair 1985). On the other hand, nonlinear CGE models are more capable of responding to price changes. But the flexible adjustment features of CGE models often results in underestimation of economic impacts (Okuyama 2007). Use of CGE models requires extensive data sets. Like IO models, the SAM framework has rigid coefficients. It also requires large data sets and produces upper bounds for the estimates (Okuyama 2007).

Researchers are constantly working to overcome the constraints of these models in order to adapt them to disaster impact analysis (Crowther and Haines 2005; Hallegatte 2008). New challenges have already come forward for disaster impact assessment (Okuyama 2007). How can both the negative (devastation) and the positive (recovery and reconstruction) effects of a disaster be dealt with within a certain time frame using an economic modeling framework? How do economic structures respond to disasters across regions? How do people react in an emergency situation? Knowledge about these questions becomes necessary to understand what actually happens in a disaster.

Each hazard is unique not only in its characteristics but also on its disastrous outcomes. While the ground shake of an earthquake may continue for 30 s, cyclone-induced flooding may continue for more than a month. Hazards also create varied impacts over space. No two cyclones passing through the same area have identical regional impacts. Efforts to address the dynamic nature of disaster situations must have a better understanding of their impacts. Inter-regional IO models explicitly attempt to include a spatial dimension into economic modeling. A two-region inter-regional IO table is employed by Okuyama and his colleagues (1999) in order to estimate the induced effects of the 1995 Kobe Earthquake. One of the two regions includes the area where the earthquake occurred and the other encompasses the rest of Japan. In 2004, Okuyama used Miyazawa's (1976) extended version of a conventional IO

framework to analyze the spatial impact of the Great Hanshin Earthquake.

Application of spatial computable general equilibrium (SCGE) models is found in the work of Tsuchiya and his colleagues (Tsuchiya et al. 2007; Tatano and Tsuchiya 2008). They have integrated a SCGE model with a transportation model and estimated the effects on interregional flows of freight and passengers due to damage inflicted on the transport infrastructure caused by earthquake scenarios in Japan. The model indicates that restriction applies on the movement of labor and capital once a disaster takes place. The results clearly demonstrate that economic losses arising from a disaster situation are distributed in a varied scale across regions. The spatial dimension is also introduced by Cole (1998), when he used a multicounty SAM together with a geographic information system (GIS)-based location data set to investigate socioeconomic and interregional impacts for disaster preparedness.

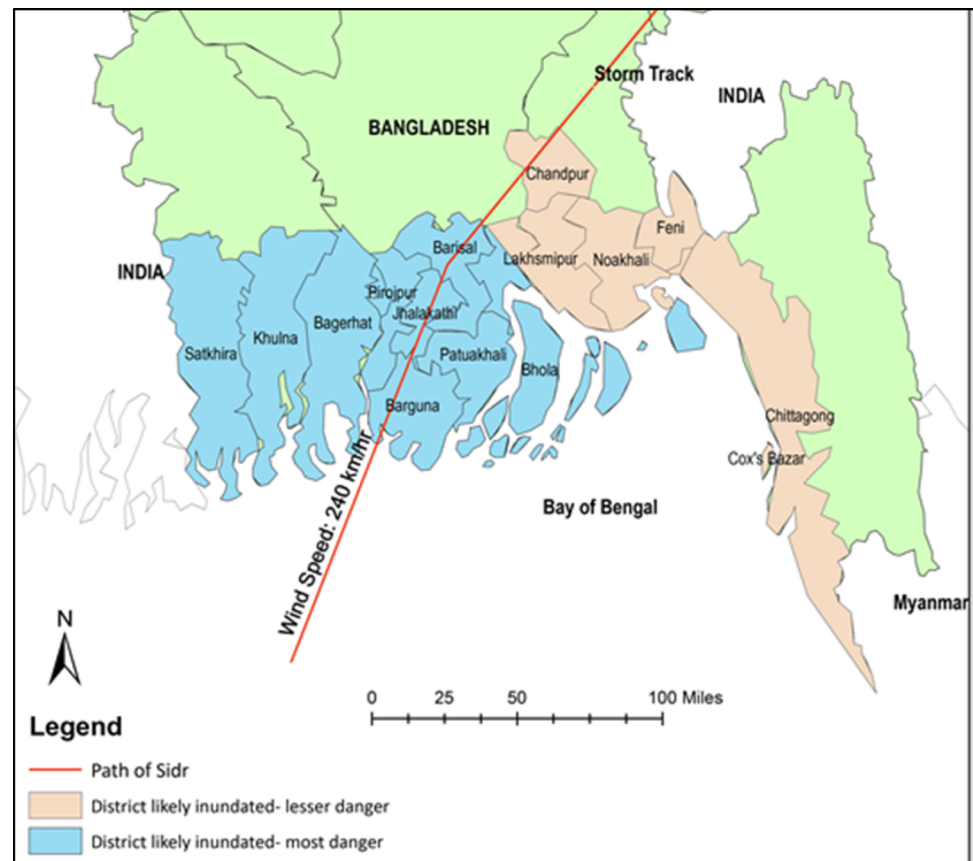
The present study selects an IO framework to assess the cyclone disaster impacts. In the absence of an interregional IO table for Bangladesh, this research uses the simple framework of a national IO table to identify interaction among different sectors of the regional economies of Bangladesh. The direct and indirect damage due to a cyclone involves both physical and societal aspects and requires adaptation and mitigation measures, which have been reported in several studies undertaken in Bangladesh (WFP 2007; GoB 2008; MoFDM 2009; UNDP 2011; World Bank 2011; Chowdhury 2012), but these studies are limited in their scope while assessing induced losses. These studies have considered localized effects of disaster but have failed to address the economics of disaster events at higher spatial levels.

In the current research, the national IO table for the Bangladesh economy is disaggregated into six regional IO tables for the six divisions of Bangladesh: Barisal, Chittagong, Dhaka, Khulna, Rajshahi, and Sylhet. Two scenarios developed for the 2007 cyclone Sidr using direct damage, consumer spending, and public/private investment data and regional IO models are used to simulate the impact of these scenarios on economic sectors of the six major administrative districts. Cyclone impacts are estimated in terms of changes in output, income, and employment both nationally and regionally.

4 Cyclone Sidr

Cyclone Sidr (a category IV storm on the Saffir-Simpson hurricane scale of I to V) was selected as a representative hazard event for this study in which regional economic impacts are estimated. Sidr, with a maximum wind speed

Fig. 2 Path of cyclone Sidr and Sidr-affected districts in coastal Bangladesh
 Source https://en.wikipedia.org/wiki/Cyclone_Sidr



of 240 km/h, tidal waves up to five meters high, and storm surges at a maximum of 10 meters in some areas, struck the southwest coast of Bangladesh on 15 November 2007 (GoB 2008). The hazard event caused extensive destruction of infrastructure such as houses, roads, bridges, embankments, and utility and service facilities. Drinking water became saline and was contaminated by wastes. Around one million households near the southwest coast were severely affected and another 1.3 million were impacted to some degree. The death toll was estimated at around 3406 (GoB 2008). Thirty out of 64 districts of Bangladesh were affected by Cyclone Sidr. Nineteen coastal districts were virtually shattered. Figure 2 shows the path of cyclone Sidr and Sidr-affected districts.

5 Data Sources and Estimates

To estimate the impact of cyclone Sidr, this study first develops cyclone scenarios with the help of secondary data sources. It uses different government, nongovernment, and World Bank (WB) reports, for example, WFP (2007), GoB (2008), World Bank (2010), and utilizes published articles by Karim (2011) and Chowdhury (2012) to formulate two scenarios: (1) direct damages across the economic sectors

due to Sidr; and (2) in addition to direct damages, changes in government investment decisions and the spending practices of individual consumers in response to cyclone Sidr.

In order to estimate the impact of these scenarios upon regional economies through an IO model, the damage, public expenditure, and investment data had to be converted into monetary values. Therefore, loss of human lives was removed from this analysis. According to GoB (2008) estimates, cyclone Sidr caused direct damages worth of 115,569 million BDT¹ (USD 1521million). Housing services and the agriculture sector were devastated by the cyclone.

Direct damages at the national level were downscaled to create regional damage figures (Table 2). National damage figures were multiplied by the regional share of damage in order to prepare regional damage data for the six regions. The administrative district share of damage for a region is the ratio of area affected in the region to the area nationally affected by Sidr.

Cyclone Sidr inflicted indirect impacts on both individuals and government. Sectoral output production decreased due to the cyclone and storm surge. Job losses

¹ 1 US\$ = 76 Bangladeshi Taka (BDT) on an average.

Table 2 Regional damage to sectors due to cyclone Sidr

Share of damage and damage to sectors	National	Damage in regions (divisions) (million BDT)					
		Dhaka	Rajshahi	Khulna	Sylhet	Barisal	Chittagong
Share of damage	1.00	0.06	0.00	0.27	0.00	0.32	0.35
Agriculture	30,197.00	1811.82	0.00	8153.19	0.00	9663.04	10,568.95
Industry	2297.00	137.82	0.00	620.19	0.00	735.04	803.95
Construction	17,483.00	1048.98	0.00	4720.41	0.00	5594.56	6119.05
Housing services	57,915.00	3474.90	0.00	15,637.05	0.00	18,532.80	20,270.25
Professional and miscellaneous	6419.00	385.14	0.00	1733.13	0.00	2054.08	2246.65
Trade services	1258.00	75.48	0.00	339.66	0.00	402.56	440.30

Source GoB (2008), World Bank (2010)

were also evident, which eventually affected both producer and consumer. Purchasing power of people declined. The government altered its investment expenditures to ensure that relief funds were available, that construction of cyclone shelters, roads, and polders could take place, and that damaged infrastructure would be rehabilitated and maintained. At the individual level, a major portion of investment was dedicated to repair houses in cyclone affected regions. Table 3 shows the national aggregate data on change in consumer expenditure and public/private investment across different sectors. The regional data are estimated using the regional share of the number of households that experienced reduced consumer spending as a result of cyclone Sidr, as well as the regional share of decreased public/private investment in infrastructure.

More detailed information on spending and investment both at regional and sectoral levels after cyclone Sidr would have been useful to avoid over or under estimation during our impact analysis. Because data are often poor in quantity and quality, scenario preparation and computer simulation, based on the projection of the most reliable data sets available, are most likely to generate findings upon which policymakers can formulate cyclone-based, risk-sensitive regional policies.

The National input–output table for Bangladesh's economy in 2006–2007, which was prepared immediately before cyclone Sidr, was employed in this study. National and regional GDPs were used to calculate the regional IO tables for each of the six regions. The yearly GDP data for six regions of Bangladesh were available from 1981–1982 to 1999–2000. Therefore, the regional GDPs for 2006–2007 were extrapolated by regression methods using the 1981–2000 data. Sectoral national income and employment data were used to estimate income and employment multipliers.

6 Methodology of the Study

The National Input–Output table for the Bangladesh economy in 2006–2007 consists of 86 economic sectors. These economic sectors are first aggregated into 11 major economic sectors: (1) agriculture; (2) industry; (3) construction; (4) power, gas, water, and sanitary services; (5) mining and quarrying; (6) trade services; (7) transport, storage, and communication; (8) housing services; (9) professional and miscellaneous; (10) public administration and defense; and (11) banking and insurance. The aggregated national IO table can be expressed as follows:

$$X^N = (I - A^N)^{-1} Y^N$$

X^N and Y^N are the output and final demand (including household consumption, government purchase, and export) matrix of the nation respectively. I is the identity matrix and A^N is the square matrix of the technical coefficients for the nation. The technical coefficient, a_{ij} is defined as the ratio of flow of input from sector i to j to total output of sector j .

The location quotient (LQ) method is applied to formulate six regional IO tables from the aggregated national table for the year 2007. The LQ for region R and sector i is defined as:

$$LQ_i^R = \left(\frac{G_i^R}{\sum_i G_i^R} \right) / \left(\frac{G_i^N}{\sum_i G_i^N} \right)$$

where G stands for the GDP data, the superscript R and N , respectively denote region and nation. The regionalization criteria for the method are as follows:

$$\begin{aligned} a_{ij}^R &= a_{ij}^N (LQ_i^R) & \text{if } LQ_i^R < 1 \\ a_{ij}^R &= a_{ij}^N & \text{if } LQ_i^R \geq 1 \end{aligned}$$

Table 3 Changes in consumer spending and public/private investment of national economic sectors due to cyclone Sidr, 2007–2008

Economic sectors	Decrease in consumer spending (million BDT)	Change in public/private investment (million BDT)
Agriculture	4271.61	–
Industry	6407.42	–
Transport, storage, and communication	–	39.85
Housing services	–	867.96
Professional and miscellaneous	–	9521.00
Construction	–	18,883.00

Source WFP (2007), GoB (2008), Karim (2011), World Bank (2011) and Chowdhury (2012)

Therefore, the regional IO system now takes the form of the following:

$$X^R = (I - A^R)^{-1} Y^R$$

X^R and Y^R are the output and final demand matrix of region R respectively. I is the identity matrix and A^R is the square matrix of the regional technical coefficients.

The output, income, and employment multipliers for national and regional economic sectors then are calculated. The output multiplier helps to trace those sectors of the economy where additional spending will have the greatest impact in terms of monetary value of output generated throughout the economy (Miller and Blair 1985). The income multiplier translates the impacts of output changes into changes in income received by households. The employment multiplier is calculated based on the relationship between the value of output of a sector and employment in that sector.

To identify the key sectors of national and regional economies, backward and forward linkage multipliers are derived. The linkage multipliers trace how an economic sector is dependent on other sectors in both backward (the concerned sector uses input from other economic sector) and forward (the concerned sector's outputs are used as inputs by other economic sectors) directions. The usual interpretation is that if values of both the linkage multipliers are greater than one, then the sector will be considered as a key sector for the economy. Identification of key sectors in an economy is important in the sense that any investment in the key sector will boost the economy through its backward and forward linkages with other economic sectors.

For disaster impact assessment both at the national and the regional levels the following formula are used:

$$\Delta X^N = (I - A^N)^{-1} \Delta Y^N \quad \text{and} \quad \Delta X^R = (I - A^R)^{-1} \Delta Y^R$$

ΔX^N and ΔX^R are the changes in national and regional output due to ΔY^N and ΔY^R induced changes in national and regional final demand vectors respectively. Values of ΔY^N and ΔY^R are derived from Tables 2 and 3 for identifying

the impacts of scenario 1 (direct damages across the economic sectors due to Sidr); and scenario 2 (in addition to direct damages, changes in government investment decisions and the spending practices of individual consumers in response to cyclone Sidr) respectively. To estimate income and employment changes, the sectoral changed outputs are multiplied by the respective income and employment multipliers.

The aggregation, regionalization, and multiplier, key sector and impact analyses were carried out by Python input–output (PyIO) module developed by the Regional Economics Applications Laboratory (REAL), University of Illinois, Urbana-Champaign.²

7 Analysis and Interpretations

This section first discusses the national and regional variations in output, income, and employment multipliers, sectoral linkages, and key sectors. Then it describes the impact of cyclone Sidr on national and regional output, income, and employment.

7.1 Output Multiplier

During 2006–2007, the most promising sector for the economy of Bangladesh was the construction sector. Different construction activities related to development projects in two large economies of the country—Dhaka and Chittagong had contributed to the highest value of its output multiplier. The output multiplier of this sector was as high as 2.077. At the national level, the lowest value (1.328) was found for the housing services sector. The output multipliers for the industry and the agriculture sectors, which contributed around 39 and 19 % of the total national output, were 1.920 and 1.885, respectively.

The regional output multipliers were greater than 1.5 for four economic sectors: agriculture; industry; construction; and mining and quarrying sectors. Multiplier values were

² <http://www.real.illinois.edu/>.

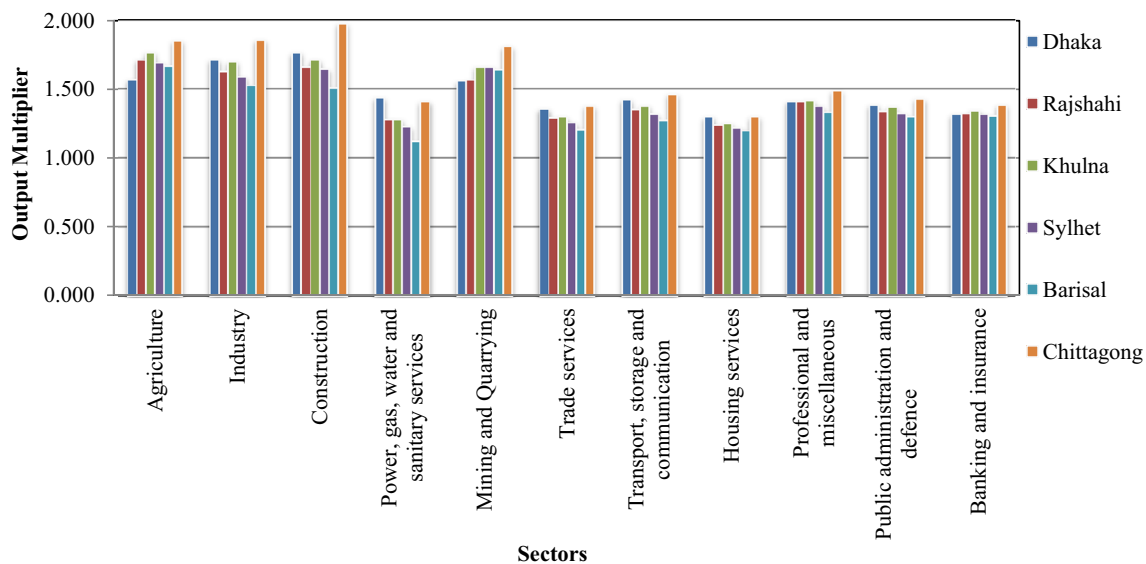


Fig. 3 Variation in sectoral output multiplier for six regions, 2006–2007

lower for power, gas, water, and sanitary services; trade; and housing services. Significant variations were observed in sectoral output multipliers across the regions. For example, in terms of output multipliers, Barisal lagged behind in all the sectors. Due to its exposure to natural hazards like flood, cyclone, storm surge, and saline water intrusion, Barisal had always failed to attract entrepreneurs to invest on its economic sectors. This might have caused the lower values of output multipliers for Barisal's economic sectors. In contrast, Chittagong scored the highest values. The multiplier values of Dhaka and Khulna were also relatively high. Figure 3 depicts the variation in output multipliers for the six regions of Bangladesh.

7.2 Income Multiplier

Nationally, housing services, trade services, and transport, storage, and communication sectors had higher potential to increase household income, reflected in their respective income multipliers, than all other multipliers. The values were respectively 0.975, 0.948, and 0.939. The income multiplier was the lowest (0.646) for industrial activities, although the sector's contribution was the highest in the total national output of Bangladesh. Haque and Jahan (2015) interpreted the low employment and wage rates in this sector as the reason behind industry's lowest value as an income multiplier.

Figure 4 reveals the variation in sectoral income multipliers for six regions of Bangladesh. Sylhet region secured the highest rank across all economic sectors. The income multipliers of Sylhet ranged from 4.11 (trade services) to 2.35 (mining and quarrying sector). The

combination of economic sectors in Sylhet region strongly supported increased household income. Remittance earning by expatriates of Sylhet living abroad also had significant contribution in such high income multipliers of economic sectors of Sylhet. In contrast, Dhaka's position was the lowest of the regions in terms of its income multiplier. For Dhaka, the values ranged from 0.4 (for trade services) to 0.21 (in the mining and quarrying sector). This performance indicates that although job opportunities were varied in Dhaka, their potential to generate household income was minimum and living cost was also high in this region. Trade services exhibited the highest value of income multipliers in all regions, ranging from 0.4 (Dhaka) to 4.11 (Sylhet). The multiplier value was the lowest for the mining and quarrying sector.

7.3 Employment Multiplier

According to the Bangladesh Labor Force Survey (BBS 2006), in 2005–2006 approximately 48 % of the national workforce was employed in the agriculture sector. The second most labor intensive sector was trade services, comprising 16 % of the country's work population. In contrast, the housing sector involved only 0.5 % of the national work force. These findings are also reflected in the employment multiplier calculated from the national IO table for 2006–2007. The multiplier value was the highest (1.8×10^{-5}) for the agriculture sector. The trade sector trailed with a value of 1.0×10^{-5} . The lowest employment multiplier (0.2×10^{-5}) was found for the housing sector. For the industry sector, the value of the multiplier was 0.7×10^{-5} .

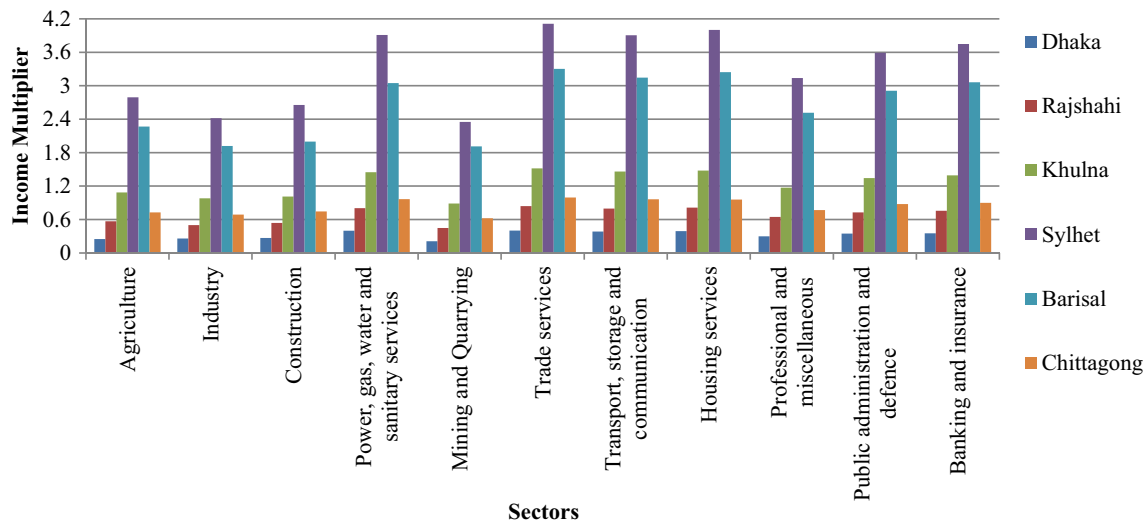


Fig. 4 Variation in sectoral income multiplier for six regions, 2006–2007

A quick perusal of Fig. 5 shows that regional variation in the sectoral employment multiplier followed a similar pattern to the employment multiplier at the national level. Based on the sectoral employment multiplier, in a comparison of all the six regions Sylhet scored the highest value in all sectors. After the Sylhet region, the multiplier scores were higher for Barisal and Rajshahi. The economies of Barisal and Rajshahi were mainly agriculture-based. The majority of their population was involved in agriculture-related activities (directly on agriculture and directly/indirectly on trade and/or transport, storage, and communication services). Therefore, the employment multipliers for the mentioned sectors were relatively high. Dhaka's already saturated formal sector made Dhaka the least successful region for employment generation (Haque and Jahan 2015).

7.4 Backward and Forward Linkages and Key Sectors

Having both backward and forward linkage multipliers greater than one, the agriculture and industry sectors appeared as the key sectors for Bangladesh economy during 2006–2007. Except for Barisal, these were the key sectors for the remaining five regions. For Barisal, agriculture is the only sector among 11 economic sectors that constituted a key sector. In fact, the geographic situation of this coastal region and its exposure to natural hazards have resulted in extremely limited industrial development.

Table 4 summarizes the backward and forward linkage multiplier values for the six regions across the sectors. Although there were variations in multiplier values, in all regions the backward linkage oriented sectors were

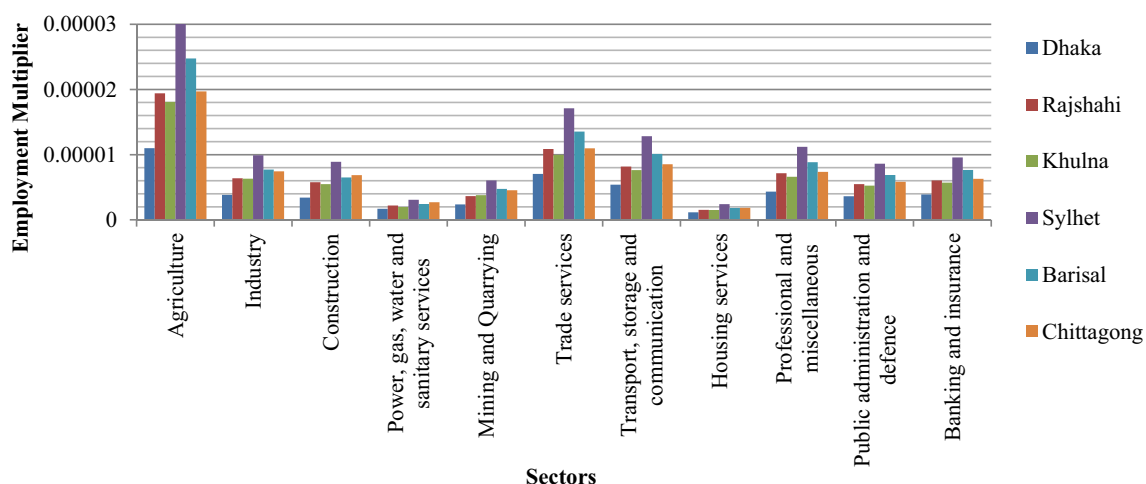


Fig. 5 Variation in sectoral employment multiplier for six regions, 2006–2007

Table 4 Backward and forward linkage (BL and FL) multipliers for six regions, 2006–2007

Sectors	Dhaka		Rajshahi		Khulna		Sylhet		Barisal		Chittagong		National	
	BL	FL	BL	FL	BL	FL	BL	FL	BL	FL	BL	FL	BL	FL
Agriculture	1.06	1.03	1.19	1.39	1.20	1.36	1.19	1.37	1.21	1.37	1.17	1.33	1.16	1.32
Industry	1.16	1.71	1.13	1.33	1.16	1.30	1.12	1.14	1.11	0.94	1.18	1.51	1.18	1.62
Construction	1.20	0.70	1.15	0.72	1.16	0.70	1.16	0.72	1.10	0.75	1.25	0.65	1.28	0.64
Power, gas, water and sanitary services	0.97	0.74	0.89	0.75	0.87	0.72	0.86	0.76	0.82	0.75	0.89	0.66	0.92	0.67
Mining and quarrying	1.06	0.70	1.09	0.74	1.13	0.76	1.17	0.85	1.20	0.88	1.15	0.77	1.13	0.75
Trade services	0.92	1.25	0.90	1.09	0.88	1.17	0.89	1.10	0.88	1.12	0.87	1.20	0.88	1.21
Transport, storage, and communication	0.97	1.14	0.94	1.03	0.94	1.09	0.93	1.03	0.93	1.07	0.93	1.09	0.93	1.08
Housing services	0.88	0.82	0.86	0.84	0.85	0.82	0.86	0.83	0.87	0.87	0.83	0.77	0.82	0.76
Professional and miscellaneous	0.96	1.32	0.98	1.58	0.96	1.58	0.97	1.63	0.97	1.67	0.95	1.52	0.94	1.49
Public administration and defense	0.94	0.76	0.93	0.73	0.93	0.73	0.93	0.74	0.95	0.77	0.91	0.70	0.90	0.70
Banking and insurance	0.89	0.83	0.92	0.80	0.92	0.77	0.93	0.82	0.95	0.80	0.88	0.78	0.86	0.77

The BL and FL values greater than 1 are represented in bold

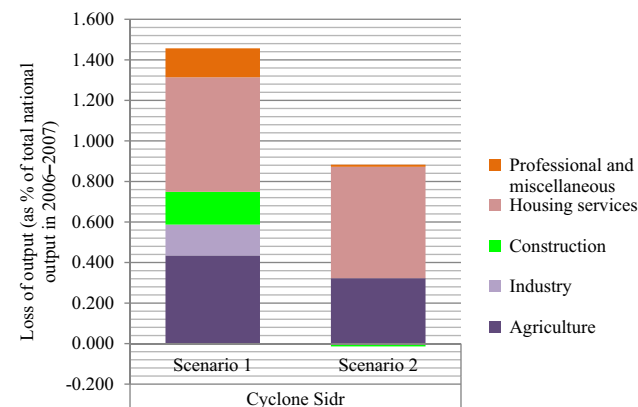
construction and mining and quarrying. In contrast, the forward linkage oriented sectors were the trade services, transport, storage, and communication, and professional and miscellaneous sectors. With both the linkage multiplier values less than one, housing services, public administration, and banking and insurance activities became the other notable sectors (neither backward nor forward linkage oriented).

7.5 Impact on National Output

Figure 6 reveals induced losses in national output of different economic sectors due to category IV cyclone Sidr. The estimated direct damages ascribed to Sidr could have caused an induced loss worth of 186,234.70 million BDT (around 1.69 % of the total national output in 2006–2007). But change in consumer spending and public/private investment during the recovery and reconstruction phase could potentially reduce the amount of loss by 0.68 % of national output. After investment, the estimated loss was

about 110,857.93 million BDT, that is, 1.01 % of total national output.

The study results demonstrate that housing services, which is neither a backward nor a forward linkage oriented sector, was the hardest hit sector impacted by the cyclone Sidr disaster. In scenario 2, when change in the final demand vector took place, the sector faced 0.55 % losses in national output. The agriculture sector, a key sector, was also severely affected by cyclone Sidr. Although the construction sector, which maintains backward linkages with other sectors, faced a loss in worth of 17,784 million BDT (0.16 % of total national output of 2006–2007), this was the only sector that received a gain, in this case a miniscule 0.01 % of total national output of 2006–2007 when investment took place. Change in consumer spending and public/private investment could reduce the amount of loss by 0.15 and 0.13 % of national output for industry and professional and miscellaneous sectors respectively. After investment, the other key sector, industry returned to its precyclone production level with a gain in worth of 323 million BDT.

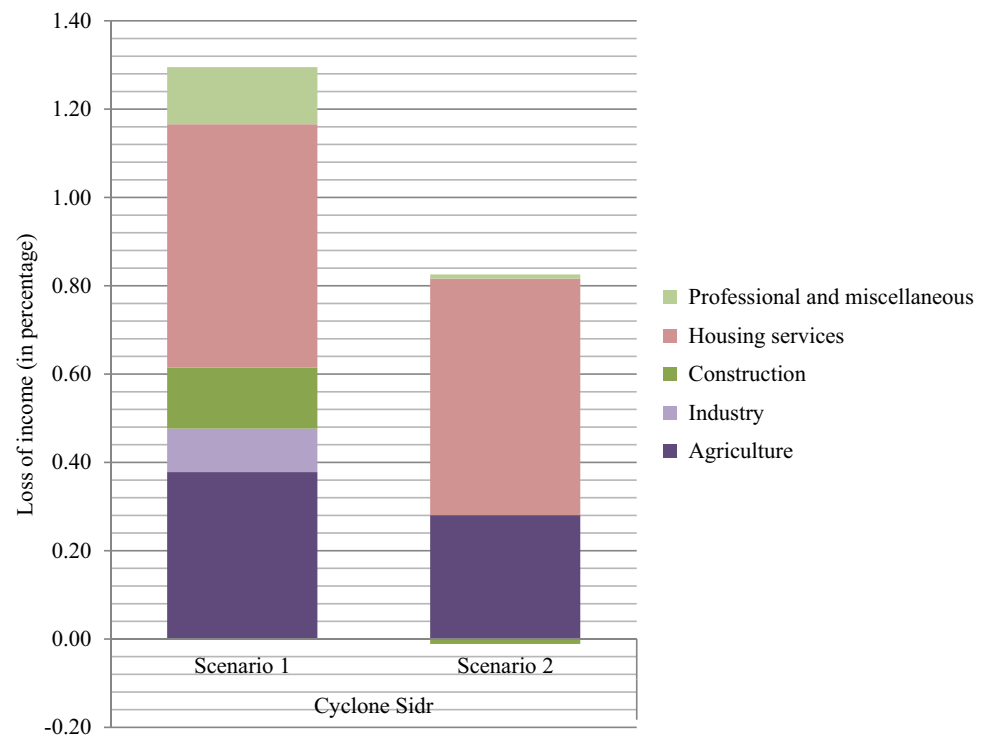
**Fig. 6** Change in national output due to Sidr scenarios

7.6 Impact on National Income

Figure 7 shows loss in income due to Sidr scenarios at the national level. The direct damages during cyclone Sidr could have caused an income loss of 1.51 % of the total national income in 2006–2007. But the recovery and reconstruction investments could reduce the amount of loss by 0.57 % of the total national income.

The loss was severe for the housing sector. Public and private investment could curtail the income loss of housing sector only by 0.01 % of the total national income. This is understandable because, people of coastal areas are in general very poor. Regularly they suffer from natural

Fig. 7 Change in national income due to Sidr scenarios



hazards (flood and cyclone) and could hardly invest significantly in housing services. On the other hand, government investment in housing services may not prove to be sustainable. Government would be better advised to invest in the construction sector that would not only help to tackle disaster situations but also would foster development initiatives in the long run. The changes in consumer spending and government investment could generate some positive gain by causing a 0.1 % increase in the total national income. The investment expenditure could also reduce the income loss by 0.12, 0.10, and 0.10 % of the total national income for the professional and miscellaneous, industry, and agriculture sectors respectively.

7.7 Impact on National Employment

Although the housing sector was the hardest hit in terms of output loss due to cyclone Sidr, employment loss was the highest for agriculture sector. As a labor intensive sector, any damage to agriculture results in major loss of employment (Fig. 8). On the other hand, because agriculture is a key sector, damage to this sector has potential negative impacts on other economic sectors, which can be further understood through backward and forward linkage multipliers.

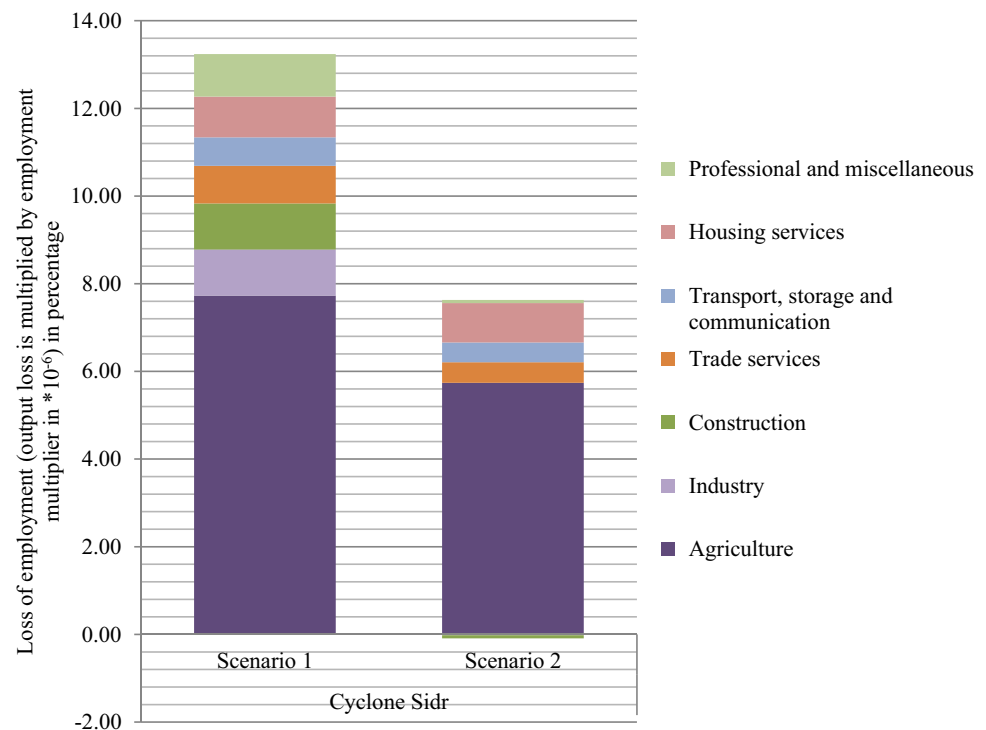
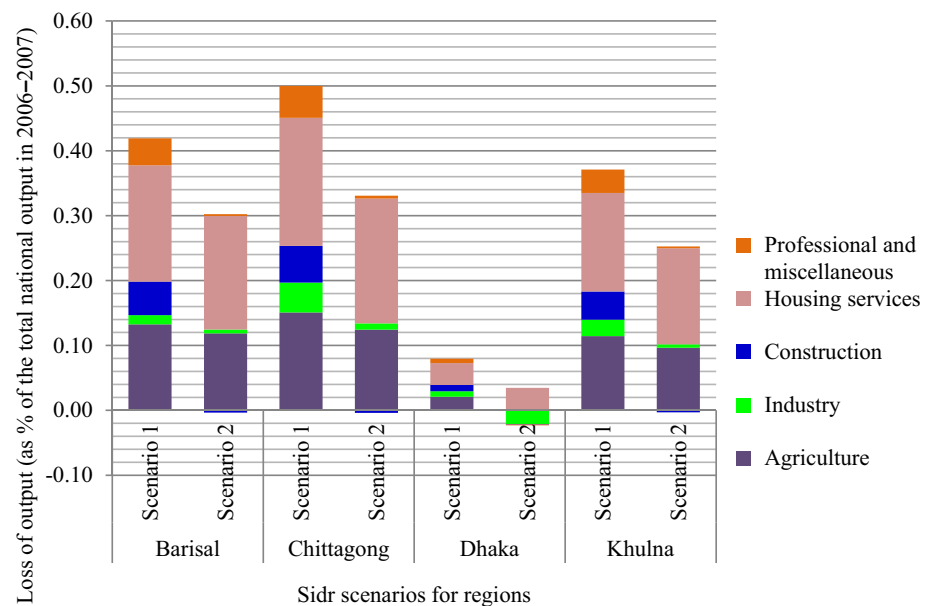
Figure 8 reveals that change in consumer behavior and investment decision in response to cyclone Sidr could reduce the employment loss almost by 1 % for the professional and miscellaneous service sector. However, change in the final demand vector could bring a 0.02 and

0.07 % employment gain for the industry and construction sectors respectively. This gain occurs because in general after any disaster government investments are mainly directed to these sectors, and thus this response ensures more job opportunities.

7.8 Impact on Regional Output, Income, and Employment

The path of cyclone Sidr suggests that the most affected regions must be the coastal districts of Bangladesh (Fig. 2). Our study on regional economic impact during cyclone Sidr also finds that output, income, and employment losses of coastal regions were severe. The three coastal regions are Chittagong, Barisal, and Khulna Divisions. Chittagong is the second largest regional economy of the country. The GDP per capita for this region stands around the national average. Here concentration of population is also high (Table 1). In contrast, the estimated GDP for Barisal Division lags far behind the national average (Table 1) and around 6 % of the nation's population lives in this region (Table 1). Khulna, another important region of the country is situated in the coastal belt. Its estimated GDP is around USD 4240 million (Table 1). About 11 % of Bangladesh's total population lives in this region, of which 18 % are urban people (Table 1).

Dhaka Division, the centrally placed region, faced some losses as the region experienced drizzle and gusty winds. Further away from the coastal regions, Rajshai and Sylhet

Fig. 8 Change in national employment due to Sidr scenarios**Fig. 9** Change in regional output due to Sidr scenarios

Divisions were not impacted by Sidr in terms of output, income, and employment losses. Figures 9, 10, and 11 depict the changes in regional output, income, and employment respectively.

7.8.1 Impact on Regional Output

Chittagong Division experienced the highest production loss during Sidr. The direct damages caused an induced

loss of about 0.58 % of the total national output in 2006–2007.

Public/private investment and consumer's expenditure created some development impetus in this region, keeping the loss at 0.38 % of the national output. Apart from Chittagong, induced losses across any economic sector were larger in Barisal than they were in Khulna Division.

Figure 9 reveals changes in regional output for Sidr scenarios. The housing services of Chittagong Division

Fig. 10 Change in regional income due to Sidr scenarios

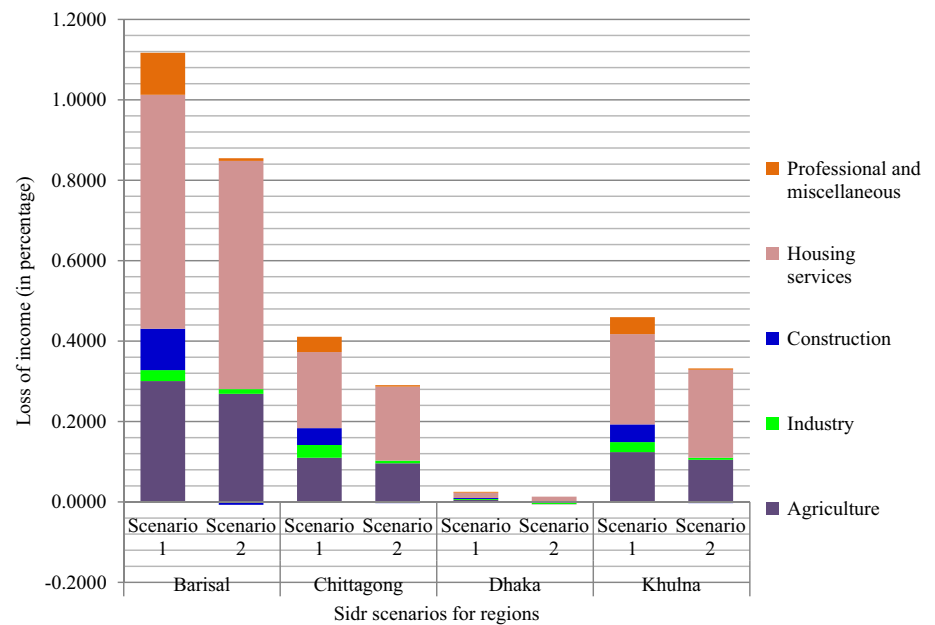
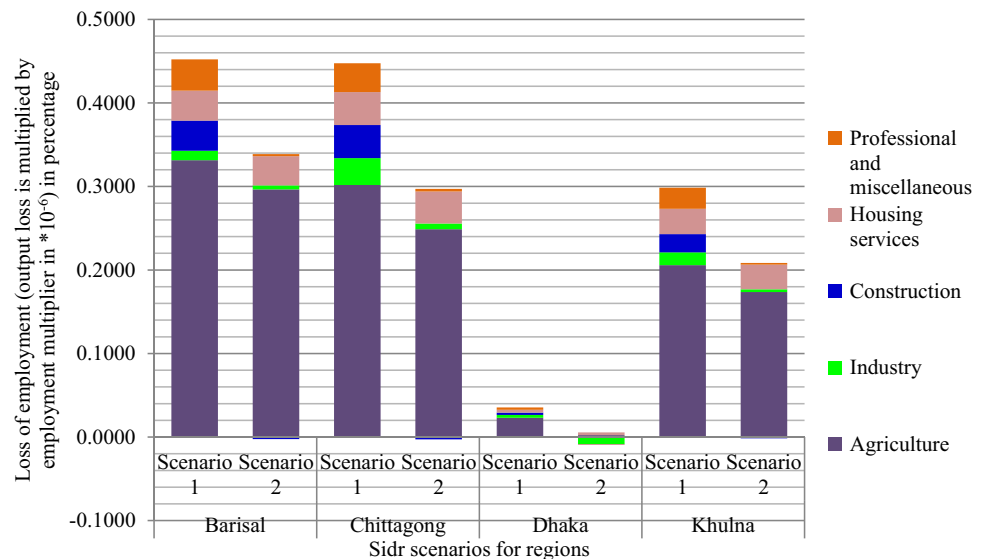


Fig. 11 Change in regional employment due to Sidr scenarios



were the hardest hit across the regions. The next sector that suffered most in any of the four other economic systems of the four regions was the agriculture sector. The construction sector, a backward linkage oriented sector, received some output gain when investments were made to handle the disaster situation. Industrial activities in Chittagong Division faced greater damage induced losses (0.15 % of the total national output) during Sidr than the other two coastal divisions—Barisal (0.13 %) and Khulna (0.11 %). The loss in the industrial sector was the least for Dhaka Division (only 0.01 %), which in fact received some positive impact with a 0.02 % production gain of the total national output when post cyclone investment was made.

Professional and miscellaneous services also suffered during cyclone Sidr.

7.8.2 Impact on Regional Income

Income multipliers were highest for the Barisal region, and Sidr's negative impact on income was the greatest for Barisal Division. While the direct damages caused approximately a 1.25 % induced loss in income, the loss reduced to 0.95 % when changes in consumer spending and public/private investment were taken into account. The other two coastal regions namely Khulna and Chittagong faced income loss of around 0.5 %.

Across the regions, loss of household income is the largest for housing services and one of the regions' key economic sectors—agriculture. Figure 10 shows the changes in regional income for Sidr scenarios. Construction was the only sector that received some income gain in all of the four regions when investments were made.

7.8.3 Impact on Regional Employment

When the induced impact of the cyclone on regional employment is examined, it is found that the loss was greatest for Barisal Division, followed by Chittagong and Khulna Divisions. Figure 11 depicts the changes in regional employment due to cyclone Sidr.

Our results suggest that agriculture-related employment is more vulnerable to cyclone impact than that in all other sectors. The next vulnerable sector is housing-related employment. For these two sectors, changes in the final demand vector bring minimal opportunity to encourage employment. The case is true for all the divisions. For the construction (backward linkage oriented), professional and miscellaneous (forward linkage oriented), and industrial activities (key sector), investment has been proved worthwhile by allowing increased opportunity of employment in the respective sectors (Fig. 11).

8 Conclusion and Policy Implications

This study investigates regional economic impacts of a category IV cyclone—cyclone Sidr. Based on secondary data, the study traces direct damages and corresponding change in consumer spending and public/private investment in response to the cyclone disaster. The research also estimates the induced effects of the disaster on national and regional output, income, and employment. The project aims to understand interaction among different sectors of regional economies during cyclone hazard. Forecasting of cyclone impacts is not at all within the scope of this study. Rather using an IO model, the Sidr effects are estimated for six regions of Bangladesh so that the nation in general and the regions in particular, can be better prepared to handle extreme cyclone events.

The study finds that a cyclone of Sidr's magnitude can induce a total output loss of 186,234.70 million BDT (USD 2450.46 million) coupled with large amount of income and job losses. The present state of investment expenditure is not large enough to handle the induced losses of a cyclone disaster. Improved forecasting and warning systems, introduction of coastal afforestation projects, construction of cyclone shelters in the cyclone-prone areas, and people's timely evacuation and safe accommodation at the shelters can minimize direct damage and loss of life from cyclone disaster (GoB 2008). But to withstand indirect and induced

losses, careful investment in regional economies is necessary for successful cyclone disaster recovery and mitigation. Not all regions of the country are equally vulnerable to cyclone disaster. The coastal regions of Bangladesh—Barisal, Chittagong, and Khulna—are more vulnerable to cyclone damage than any other parts of the country.

Our study results suggest that if a cyclone like Sidr strikes Bangladesh coast again, the induced loss of output will be the highest for Chittagong Division and that of employment and income will be greatest for Barisal Division. Housing and agriculture sectors will face the highest output and income loss, whereas job loss will be larger in the agriculture sector. But large variation in sectoral losses will be obvious if the spatial dimension is considered. For example, among the coastal regions, output loss will be most serious in the housing services of Chittagong Division and least in the housing services of Khulna Division. In contrast, income loss will be most substantial in Barisal Division's housing services. Chittagong will be the least affected division if total income loss is considered. In case of employment loss, the agriculture sector of Barisal Division will suffer the most and that of Khulna will be the least affected sector.

Housing services become severely affected by a cyclone and it is neither a backward nor a forward linkage oriented sector. Therefore, it is hard to ensure any investment in housing services sector that would rectify the situation. Nonetheless, investment should be directed towards restoration of livelihood components, including the housing services, at the recovery and reconstruction phase using the "build back better" approach (GoB 2008). As agriculture and industry are the two key sectors for the regional economies of Bangladesh, generous investment amounts should be directed into these sectors, particularly in the agriculture sector (as the sector becomes severely affected during cyclone disasters). Such investments may act as a strong force to address and mitigate potential disaster situations. Investment also can be directed towards research and development of saline water submergence tolerant crop varieties and the introduction of such modern varieties at the field level. Options for microcredit loans should be explored to increase output production of agriculture sector, particularly in a cyclone disaster recovery stage when fields are likely to be damaged by salt water intrusion. Agriculture is one of the key sectors of national and regional economies, and any gains in productivity will help diminish the inevitable loss of income and employment experienced by the households of cyclone-affected regions. Structural and nonstructural investment options in the industry and construction sectors may also prove helpful to increase output, income, and employment throughout the district economies.

Due to Bangladesh's geomorphological placement and geographical location, cyclone events have become a

regular, almost annual, phenomenon at its coast. There is an increased possibility of recurrent extreme cyclone events within the changing global climate situation. Therefore, objective formulation of disaster response policies and their effective implementation should receive due attention both at regional and sectoral level. Failure to do so will adversely affect the sectoral output, income, and employment sectors of Bangladesh with a reduction in the per capita GDP of the country as a whole.

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References

- Ali, A. 1999. Climate change impacts and adaptation assessment in Bangladesh. *Climate Research* 12(2–3): 109–116.
- Bahauddin, M. 1989. *The spatial distribution of physical facilities in Bangladesh. AIT-BUET post graduate project report*. Dhaka: Department of Urban and Regional Planning, Bangladesh University of Engineering & Technology (BUET).
- BBS (Bangladesh Bureau of Statistics). 2002. *Provisional estimates of gross regional products: 1995–96 to 1999–2000*. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh.
- BBS (Bangladesh Bureau of Statistics). 2004. *Provisional estimates of GDP, 2003–04 and final estimates of GDP, 2002–03*. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh.
- BBS (Bangladesh Bureau of Statistics). 2006. *Labor force survey 2005–06*. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh.
- BBS (Bangladesh Bureau of Statistics). 2013. *Population census 2011: National report (provisional)*. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh.
- Chowdhury, M.M. 2012. A comparative study of disaster risk reduction and post disaster livelihood recovery program in Japan and Bangladesh. http://www.adrc.asia/aboutus/vrdata/final-report/2011B_BGD_Final_Report.pdf. Accessed 15 June 2014.
- Cole, S. 1998. Decision support for calamity preparedness: Socio-economic and interregional impacts. In *Engineering and socio-economic impacts of earthquakes*, ed. M. Shinozuka, A. Rose, and R.T. Eguchi, 125–153. Buffalo, New York: Multidisciplinary Center for Earthquake Engineering Research.
- Crowther, K., and Y. Haimes. 2005. Application of the inoperability input-output model (IIM) for systemic risk assessment and management of interdependent infrastructures. *System Engineering* 8: 323–341.
- GoB (Government of the People's Republic of Bangladesh). 2008. *Cyclone Sidr in Bangladesh: Damage, loss, and needs assessment for disaster recovery and reconstruction*. Dhaka: GoB.
- GoB (Government of the People's Republic of Bangladesh). 2009. *Bangladesh climate change strategy and action plan*. Dhaka: Ministry of Environment and Forests, GoB.
- Haque, A., and S. Jahan. 2015. Impact of flood disasters in Bangladesh: A multi-sector regional analysis. *International Journal of Disaster Risk Reduction* 13: 266–275.
- Hallegatte, S. 2008. An adaptive regional input-output model and its application to the assessment of the economic cost of Katrina. *Risk Analysis* 28(3): 779–799.
- Hirschman, A.O. 1958. *The strategy of economic development*. New Haven: Yale University Press.
- Horwich, G. 2000. Economic lessons of the Kobe earthquake. *Economic Development and Cultural Change* 48(3): 521–542.
- Islam, M.A. 1978. *Planning regions: Bangladesh*. Master's thesis. Dhaka: Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology (BUET).
- Karim, Z. 2011. Assessment of investment and financial flows to adapt to the climate change effects in the agriculture sector. http://ext.bd.undp.org/CCED/bgd/BGDPMaterials/EnvironmentalGovernanceRelatedDocuments/Bangladesh_Assessment_Agriculture.doc. Accessed 15 June 2014.
- Loayza, N., E. Olaberria, J. Rigolini, and L. Christiaensen. 2009. Natural disasters and growth going beyond the averages. Policy research working paper No. WPS 4980. Washington DC: The World Bank.
- Mahmoud, C.S. 2008. Addressing regional inequality issues in Bangladesh public expenditure. Paper prepared under Pro-poor Macroeconomic Policy Study conducted by the Centre for Policy Dialogue (CPD) in collaboration with the United Nations Development Programme (UNDP).
- MoFDM (Ministry of Food and Disaster Management). 2009. Summary of cyclonic storm Aila. Dhaka: Disaster Management Information Center (DMIC), Disaster Management Bureau (DMB), MoFDM, Government of the People's Republic of Bangladesh.
- Miller, R.E., and P.D. Blair. 1985. *Input-output analysis: Foundations and extensions*. New Jersey: Prentice-Hall.
- Miyazawa, K. 1976. *Input-output analysis and the structure of income distribution*. New York: Springer.
- Noy, I.M. 2009. The macroeconomic consequences of disasters. *Journal of Development Economics* 88(2): 221–231.
- Noy, I., and T. Vu. 2010. The economics of natural disasters in a developing country: The case of Vietnam. *Journal of Asian Economics* 21(4): 345–354.
- Okuyama, Y. 2004. Modeling spatial economic impacts of an earthquake: Input-output approaches. *Disaster Prevention and Management: An International Journal* 13(4): 297–306.
- Okuyama, Y. 2007. Economic modeling for disaster impact analysis: Past, present, and future. *Economic Systems Research* 19(2): 115–124.
- Okuyama, Y., G.J.D. Hewings, and M. Sonis. 1999. Economic impacts of an unscheduled, disruptive event: A Miyazawa multiplier analysis. In *Understanding and interpreting economic structure*, ed. G.J.D. Hewings, M. Sonis, M. Madden, and Y. Kimura, 113–144. Berlin: Springer.
- PC (Planning Commission). 1998. *The Fifth Five Year Plan 1997–2002*. Dhaka: Planning Commission, Ministry of Planning, Government of the People's Republic of Bangladesh.
- Perroux, F. 1950. Economic spaces: Theory and applications. *Quarterly Journal of Economics* 64(1): 89–104.
- Rose, A. 2004. Economic principles, issues, and research priorities in hazard loss estimation. In *Modeling spatial and economic impacts of disasters*, ed. Y. Okuyama, and S.E. Chang, 13–36. New York: Springer.

- Strobl, E. 2012. The economic growth impact of natural disasters in developing countries: Evidence from hurricane strikes in the Central American and Caribbean regions. *Journal of Development Economics* 97(1): 130–141.
- Tatano, H., and S. Tsuchiya. 2008. A framework for economic loss estimation due to seismic transportation network disruption: A spatial computable general equilibrium approach. *Natural Hazards* 44(2): 253–265.
- Tsuchiya, S., H. Tatano, and N. Okada. 2007. Economic loss assessment due to railroad and highway disruptions. *Economic Systems Research* 19(2): 147–162.
- UNDP (United Nations Development Programme). 2004. A global report: Reducing disaster risk: A challenge for development. <http://www.undp.org/bcpr>. Accessed 15 June 2014.
- UNDP (United Nations Development Programme). 2011. UNDP core family shelter programme value for money evaluation. <http://www.undp.org.bd/projects/prodocs/ERF/Review%20of%20UNDP%20Sidr%20Shelter%20Programme.pdf>. Accessed 15 June 2014.
- WFP (World Food Programme). 2007. Food security assessment, Sidr cyclone-Bangladesh. http://www.lcgbangladesh.org/derweb/cyclone/cyclone_assessment/Food%20security%20assessment-IDR%20cyclone%20by%20WFP%20and%20partners_December%202007%20.pdf. Accessed 15 June 2014.
- Wilson, A.G. 1974. *Urban and regional models in geography and planning*. London: Wiley.
- World Bank. 2010. Economics of adaptation to climate change: Bangladesh. http://climatechange.worldbank.org/sites/default/files/documents/EACC_Bangladesh.pdf. Accessed 15 June 2014.
- World Bank. 2011. Climate risk and adaptation country profile for Bangladesh: Vulnerability, risk reduction, and adaptation to climate change. http://sdwebx.worldbank.org/climateportal/doc/GFDRRCountryProfiles/wb_gfdr climate_change_country_profile_for_BGD.pdf. Accessed 15 June 2014.
- Yezer, A.M., and C.B. Rubin. 1987. The local economic effects of natural disasters. Working paper No. 61. Boulder: Institute of Behavioral Science, University of Colorado.